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THE FUNCTION

OF

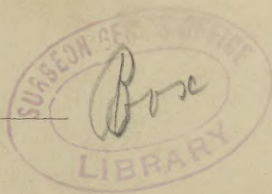
The Eustachian Tube,

IN ITS RELATION TO THE

RENEWAL AND DENSITY OF THE AIR IN THE TYMPANIC
CAVITY, AND TO THE CONCAVITY OF THE
MEMBRANA TYMPANI.

BY

THOS. F. RUMBOLD, M. D.,
SAINT LOUIS.



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THOS. F. RUMBOLD, M. D.,

P R E F A C E .

The method of supplying air to the middle ear, the density of this air, and the cause of the uniform concavity of that portion of the membrana tympani from which is reflected the "light spot," for some time seemed to have been settled. In calling this in question, it has not been without great misgivings as to my ability to adduce sufficient reasons to establish the Propositions given. My experience in the observations of the phenomena accompanying the normal and abnormal conditions of the ear has been comparatively so limited that I dread to contrast it with the learned and matured opinions of such eminent authors as Toynbee, Helmholtz, Troltsch, Hinton, Roosa, and others; and were it not for the conviction that I have facts—all of which have been repeatedly tested during the last five years—that seem to support what I have to say, I would not presume to dispute their opinions on this subject.

1205 Washington Avenue, St. Louis, May, 1873.

FUNCTION OF THE EUSTACHIAN TUBE.

In the years 1868 and 1869 I had frequent opportunities of examining the symptoms and phenomena of several cases afflicted with patency of the eustachian tube, which led me to conclusions that are in almost direct opposition to the opinions entertained by Otologists of the present day on the following subjects, viz.: 1st, the method of supplying air to the tympanum; 2d, the density of the air within this cavity; and 3d, the cause of the uniform concavity of the membrana tympani.

I will endeavor to prove the correctness of the following Propositions, viz.:

1st. That during the act of deglutition the eustachian tube is not an open passage into the tympanum.

2d. That the walls of the eustachian tube are constantly in slight contact.

3d. That the air continually permeates the eustachian tube into the tympanum, thus maintaining the normal air density in this cavity.

4th. That the air in the normal tympanic cavity is not of equal density with that of the surrounding atmosphere, the air in the tympanum being rarefied.

5th. That one of the functions of the eustachian tube is the maintenance of this normal air density.

6th. That the rarefied condition of the air in the tympanum is the cause of the uniform concavity of the membrana tympani, especially that portion of it from which the "light spot" is reflected.

It is not my intention to take up these Propositions *seriatim*, but to give a few of the cases alluded to as they occurred in practice, and

the results of the experiments and observations on them, that caused me to come to the above conclusions, and afterwards to cite experiments and additional cases for their substantiation.

The generally accepted theory of the method of renewing the air in the tympanum—first promulgated by Mr. Joseph Toynbee, F. R. S., in 1853—is, that the walls of the eustachian tube are in contact when at rest, but that they are drawn apart by the tensor and levator palati muscles at every act of deglutition to such an extent that the “air can either enter or recede from the tympanic cavity,” *thus* maintaining a tympanic air density equal with the surrounding atmosphere. The proof that is given in support of this theory, is the fact, that the act of deglutition relieves the prominent symptoms, and the main disability to the hearing that is occasioned by the inflation of the tympanic cavity. This will be designated as the “deglutition method” of tympanic air renewal.

We cannot make experiments on the eustachian tube, by instrumental means, without incurring some risk of doing injury to this important organ; but this passage is sometimes abnormally open, at others abnormally closed. On such occasions we have opportunities of judging the effect of these conditions upon (*a*) the air density in the cavity and (*b*) the concavity of the membrana tympani. Both of these conditions of the eustachian tube are very favorable for this investigation, as they can be temporarily overcome, so that the hearing may be increased equal to or beyond the patient's usual acuteness.

The phenomena observed during the *patent* condition of this passage, if carefully examined, demonstrate certain facts that appear to question the correctness of the “deglutition method” of supplying air to the middle ear.

I think that this abnormal condition of the eustachian tube, especially in its mild form, is not so rare as might be supposed from the infrequency of its mention in our works on the “Ear,” but rather that it is rarely recognized when presented. Even when the patients mention the symptoms—if not in an aggravated form—it may at once be set down as a case of tinnitus aurium presenting one of its many peculiar characteristics, and so passed, for the time, without special examination, as has occurred in my own practice on three

known occasions, although at the time I was extremely anxious to have such cases for observation, to carry on my investigations of the subject that is now under discussion.

The prolixity of the cases now to be cited will be justified by the information they will give upon this subject of increased resonance of the patient's voice in their own ears.

I take it that the following conclusion is self-evident, to-wit: If the eustachian tube is opened into the tympanum by the tensor and levator palati muscles, for the normal ventilation of this cavity, at every act of deglutition; then any cause that might open this tube, *aside* from the action of the muscles mentioned, would not, on account of this opening, be a cause of great disability to the organ of hearing.

From the symptoms accompanying the following cases presenting autophony, it is expected to prove that the mere opening of the eustachian tube, for a short or long period of time, is a cause of too great disability to the organ of hearing to admit of its being open during the act of deglutition without producing some of the same disturbing phenomena; and that, while the eustachian tube is in a patent condition, the membrana tympani is less concave than normal.

CASE I.—*Feb. 5th, 1868.*—Otto Z——, German, aged about 38 years, farmer, from Columbia, Mo., applied to be relieved from excessive noise in his left ear while talking. He had been deaf in this ear since 1862; he supposes that it was occasioned “by long exposure in the woods.” His right ear proved, upon examination, to be also affected. This phenomenon in the left ear first appeared eight days ago, and with it considerable increase of deafness and a sensation of fullness, or as if he had something in the ear. He hears his voice in this ear first. It would not be exactly correct to say that he heard all of his words at separate intervals, but they lap one upon another, producing quite a confusion of sounds. When pronouncing one short sound quickly, as “ah,” through the nose, there was no lapping, but two sounds, one following the other in instant succession; the first sound in a strong, hollow, deep tone immediately in this ear; the second one in the ordinary tone, and heard from without. Several nights ago he was awakened from sleep by a blowing sound in this ear.

On inspection of the membrana tympani of the left ear, the concavity was found to be slight. I will remark, that the curvature was not so remarkable for shallowness as to attract my attention even for the first two days of examination. It was not until I had made up my mind that the tube was abnormally open that I noticed the great contrast between this, and that of the right ear. The hearing distance with the watch (normal hearing distance about 120") with right ear was 36", left, on slight pressure. On examination of the pharyngo-nasal cavity, it was found occupied by a large accumulation of offensive muco-purulent secretion, the whole mucous membrane being affected with a chronic inflammation. The mouth of each eustachian tube was quite large, they also partaking of the same general congestion.

While examining his case he twice asked me if I could not hear him talk through the left ear; the sound of his voice in this ear was so loud to himself that he thought others must hear it also.

The posterior nares syringe was used with warm salt water (3j-Oj) to clean out the offensive secretion above and behind the soft palate. The first injection washed out a large quantity of this matter. After the recovery from the choking sensation occasioned by the injection, he found, upon answering a question, that the sound of his voice in the left ear had disappeared. It required nearly one quart of water to clear out the pharyngo-nasal cavity.

Feb. 6th.—The sound of his voice in the left ear was absent for nearly two hours after the last treatment, returning after he had used his handkerchief to blow his nose. The posterior nares was again washed out, using about half a pint of warm salt water. The first syringeful again stopped the phenomenon.

Feb. 7th.—The sound of his voice in this ear did not return for three hours after the last treatment, happening this time without any known cause. Last night he was again awakened by the blowing sound in this ear; this is still present. As the patient insisted on my listening to it, I took the aural auscultating tube* and placed it in this ear. With the aid of the instrument, I found to my great surprise that the blowing sound was occasioned by his respirations.

* I consider this a preferable name to that of "otoscope," or "diagnostic tube," being more descriptive of the use of the instrument.

It was much more distinct when he breathed through his nose with his mouth closed, then it sounded somewhat like blowing over the mouth of an old-fashioned ounce bottle; when his mouth was open it could not be heard so distinctly; and when he breathed only through his mouth it was not heard at all. His voice, as heard from his ear, while not near so loud, had the peculiarity of the hollowness and proximity that can be illustrated by placing the stethoscope near the larynx.

After one injection of the warm salt water, all the peculiarities of the case were lost, but were made to return again—except the hearing of the respiration—by the repeated blowing of the nose. The aural auscultating tube was again applied to this ear, and the previous observation confirmed. Another douche with the syringe again shut out the sounds, but were caused to return by more blowing of the nose. Politzer's air douche was not used for fear of injuring the membrana tympani thus exposed.

Feb. 8th.—The relief from hearing his voice in this ear lasted until he fell asleep. On awaking this morning he found the symptoms the same. Says that the upper and posterior portion of his throat is somewhat painful, and that his hearing is not quite so good. Watch heard in right ear, 30", in left same as before stated. The same examination with the aural auscultating tube, and the use of the syringe, fully confirmed yesterday's observations, the only difference being that it required greater exertion on the part of the patient to clear the tube after it was filled with water.

Feb. 10th.—The patency did not return until yesterday morning, being absent about twenty-four hours. Has more pain in the head than usual; tinnitus in right ear; hearing in this ear 28". According to directions, yesterday he snuffed warm salt water into his left nostril, while his head was inclined to that side. After repeated efforts, this had the effect of shutting off the sound of his voice from this ear, but the relief was not of long duration. The same examination with the aural auscultating tube, followed by the use of the posterior nares syringe, was repeated to to-day as often as the eustachian tube could be cleared of fluid by blowing the nose, confirming all that was before observed.

Feb. 11th.—The tube did not open until about ten o'clock last

night. This morning he was successful in forcing water from his mouth up behind the soft palate into his nose, while his head was inclined to the left side. This stopped the sound of his voice in this ear, lasting for an hour or two, or until he coughed or blew his nose, when he could again stop the sound of the voice with more water.

This plan of experiments and observations was continued every other day until the 24th of February, at which time the autophony was permanently shut off. This was apparently brought about by the application of a grs. x solution of argenti nitras to the mouth of the left eustachian tube, by means of a sponge, and held there about two seconds.

On the 2d of March he could hear the watch with this ear when it was just away from contact, on the 6th when $\frac{1}{2}$ " from it. The membrana tympani was now *more concave*, and the "cone of light" smaller and brighter (6th Proposition). The hearing with the right ear on the 6th of March, 34 ". Although this is two inches less than when he first presented himself, yet he claims that he can hear very much better, especially that he is not so much in doubt as to the direction that sounds come from.

After the experiments and observations on the 7th of February (1868), I considered that the case had demonstrated itself to be that of an abnormally open eustachian tube, and then conceived the idea that it was necessary to have this passage constantly closed for normal hearing. Soon after this my doubtful opinion was converted into almost positive conclusions by finding that Mr. Toynbee made a mistake in his first experiment, given to prove the correctness of his theory; * also that he was in error in the diagnosis of his cases of this same class, reported on page 155 of his work.

CASE II.—About the latter part of March, 1868, I noticed my friend, Dr. Charles K——, of the firm of A. M. Leslie & Co., of this city, close his nostrils with his thumb and forefinger, instantly making an inspiratory effort while his mouth was also closed. The reason for this procedure instantly came into my mind. I made the remark to him at the time, that he abstracted air out of his tympanic cavity to drive away a disagreeable fullness in the ear, and prevent the

* Toynbee on "Diseases of the Ear," page 192.

sound of his voice from reaching it, and also to increase his hearing. He replied that I was right, stating that he was frequently (may be forty to fifty times through the day) compelled to do so after taking a cold in the head, which he was very subject to. Not long after this I had an opportunity of examining his right ear (the one affected), and found that previous to the abstraction of air from the cavity the *membrana tympani* was but slightly concave, the "light spot" and whole surface dull; but as soon as he made a quick inhaling effort, with mouth and nose closed, the dullness disappeared, the concavity was increased, and with this change the removal of the sensation of fullness in the ear, the muffled, deep sound of his voice, at the same instant the increase of his hearing for outside sounds. (4th, 5th, and 6th Propositions.)

February 8th, 1872, he informed me that at one time, when greatly troubled with this autophony, he used Politzer's air douche with immediate though not lasting benefit.

CASE III.—The next case of this character that came under my observation was (Jan. 8th, 1869,) Mrs. Mary E. T——, aged about 28 years. She was also a patient of Dr. M. A. Pallen, of this city, for uterine disease. Had been, until last year, a school teacher. Her hearing in the left ear has been affected for about five years; in the right, about one year.

The interesting symptom in this case was the direct transmission of her voice through the left eustachian tube to the left ear. This could be considerably increased by yawning, at the same time breathing out through the nostrils; while in this condition, with the aural auscultating tube introduced into this ear, the deep, hollow sound of the voice could be easily heard. All deep tones were much more manifest. The "ing" in pronouncing "morning" was very distinct.

On the 19th of January the eustachian catheter was introduced well into the mouth of this tube; with the aural auscultating tube it was noticed that the sound of her voice was nearly shut off, but the flapping or purring sound of the catheter was very marked, seeming right in my ear. After an inflation by this means, she noticed that she could keep the eustachian tube closed a little longer after an inhaling effort similar to Dr. K.'s.

After injecting warm water, having a little slippery elm dissolved

in it, into the left nostril, while the head was inclined to that side, the sound of her voice was shut out from her ear for several hours.

When the eustachian tube was patent, so that her voice could be heard through it with the aid of the aural auscultating tube, the "cone of light" was broad and dull in luster, but instantly, on performing the act of deglutition with the nostrils closed, especially on making a quick inhaling effort, it became smaller and brighter, proving conclusively an increase of the concavity of the membrana tympani by rarefaction of the air in the cavity and closure of the eustachian tube: at the same instant the hearing of her voice, abnormally, in this ear was cut off, but the hearing of external sounds increased.

I might relate a few other cases having the same phenomena that have come under my observation, but will only add the following two, viz.:

CASE IV.—Rev. Dr. B. F. C., of this city, aged about 50 years. About nine years ago his left ear was injured by an unexpected discharge of a cannon near him. Three years ago Dr. A. S. Barnes, of this city, recommended him to consult me about the ear. On examination of the membrana tympani it was seen to be very concave, the "bright spot" quite small, showing that the eustachian tube did not allow sufficient air to pass into the tympanic cavity; the pharyngo-nasal space was found to be affected with chronic inflammation of the mucous membrane. For this he received a long course of treatment, but with indifferent success.

On Jan. 24th, 1872, he consulted me for a directly opposite disease of the eustachian tube, that of patency—hearing his voice abnormally loud in this left ear. This was apparently occasioned by a severe cold in the head. His voice sounded to him as though it was immediately in the ear, and seemed double, or as though some one was talking just back of his left ear. This was so very annoying that he could not think with freedom while speaking. On one occasion he was compelled to desist from preaching on account of it. Accompanying this, was fullness in the ear and increased dullness in hearing.

With the aural auscultating tube the peculiar sound of his voice could very easily be heard. The greatest contrast between any two

sounds heard from this ear was that of “a” and “ing;” the former could scarcely be heard; the latter was remarkable for its penetrating power to my ear.

Strong pressure on the tragus, closing the auditory meatus, decreased the autophony, but did not entirely check it. For the purpose of ascertaining whether or not it was the mere pressure that caused this disappearance, I had him press equally as strong into the meatus the end of the aural auscultating tube; this had *no effect* whatever upon the autophony. I then placed a piece of sheet rubber over the end of the tube and pressed as before; this had the same effect as the finger. These experiments were repeated *several times* with the same result.

Two drops of warm salt water placed into the auditory meatus (preparatory to the application of the constant current of electricity for the treatment of the disease) had no apparent effect in checking the phenomenon; three drops more decreased it a little. When the canal was about half full there was still a little resonance on phonation; but when it was as full as it could hold, there was none at all.* This experiment was not repeated. The electricity removed every symptom of patency for several days, and when it returned it was so slight that I could not hear his voice at all from the ear.

CASE V.—*March 27th, 1872.*—Miss Mollie K.—, of this city, aged 19 years. She has had perforation of both membranæ tympani and otorrhœa in both ears since she was a small girl. The following are the symptoms of her autophony, in her own words, viz.:

“I have had breathing in my right ear many times during the last winter, and up to the present time, each attack lasting sometimes an hour or two. At such times I have but little matter in my ear, and feel as though something had moved away; then I hear the sound of my breathing. I always drive this away by syringing my ear with luke-warm water. It is such an unsufferable feeling that I have to keep washing out my ear until it stops. As soon as the water stops going into my throat, then I know that the sounds will stay away.”

* These two experiments on this and the following case were suggested by reading Dr. Brunner's article, in the Arch. Opht. and Oto., Vol. II, No. 1, page 110. 1871.

Question.—What does the noise in your ear resemble ?

Answer.—"It sounds like a very loud breathing in the head, striking the ear drum quite hard ; and, if I speak, it sounds as if I were in an empty room, and as though I heard the echo of my voice. It is not the voice that comes from my mouth that hurts and sounds so loud in my ear, but that part of it that goes to my ear from my throat. The voice that comes from my mouth sounds last, and is like the echo in the room. I never speak loud at those times, because it hurts the ear drum and causes my head to ache very bad."

Ques.—What is the condition of your ear when this occurs ?

Ans.—"It occurs at a time when I have a very bad cold in my ear, and when it is not running ; at the same time my nose is hot and dry. My breath coming from my ear into my throat is very offensive."

Ques.—Is your hearing more difficult at such times ?

Ans.—"No ; I hear as well at any time ; sometimes I think that I hear better."

Ques.—Have you ever tried to stop this unusual sound of your breathing by closing your ear with your finger, or anything else ?

Ans.—"Oh, yes ; but that does no good ; it only keeps me from hearing other persons."

Ques.—Did it not stop the noise a little, and make you feel a little better ?

Ans.—"Not in the least [with emphasis] ; nothing but something run away into my ear would do any good. Sometimes, after washing my ear with water, the sounds would [after being away] soon begin to return, then I have wet the cotton with glycerine and put this in it, if I felt it [the resonance] coming on I would squeeze the cotton a little, so that some of the glycerine would run farther into my ear ; at the same time I would hold my head on my left shoulder ; then the breathing sounds would stop."

The important facts observed during the pathological stage of the first three cases, and sustained by the fourth, that I wish to be kept prominently in view, are as follows, viz. : *a*, sensation of fullness in the ears ; *b*, decreased hearing ; *c*, increased resonance of voice in the ear affected ; and *d*, decreased concavity of their membranæ tympani, all occasioned by the eustachian tube being open. Now,

there is no disputing but that the air densities on both sides of their membranæ tympani were equal; therefore, according to Toynbee and Troltsch, this condition of the eustachian passage; of the tympanic air density; and of the curvature of the membrane—because it was a consequence of the others—should not have given rise to so great a disability in their hearing; because they insist that these conditions are in accordance with the physiological functions of the ear.

To show that preconceived opinions have not biased my observation of these cases, a few more of the same class will be placed before the reader, which were observed and reported by Aurists whose opinions of the cause of the phenomena attending them are entirely at variance with those presented in this paper. The first that will be given are three mentioned by Mr. Toynbee. The close resemblance of the prominent symptoms to those cases just related are very manifest. They are found on page 155 of his valuable work on the "Diseases of the Ear," under the head of "Relaxation of the Fibrous Laminæ of the Membrana Tympani." He states that "The causes of this are—1st, the effects of an ordinary cold, producing hypertrophy of the mucous layer; 2d, inflammation of the fibrous layers. From either of these causes the membrana tympani may lose its natural resiliency, and become flaccid, so as to fall inward and approach more nearly the promontory than is natural."

I wish to remark, in advance of the comparison to be instituted between his theory of the cause of their disability in hearing, and the facts which are developed by the history of his cases, that it is not possible for the membrana tympani to fall *inward* because of any degree of relaxation. It is well known that its inclination is such that the upper margin is 6 mm. nearer the external orifice of the ear than the lower. It is evident that every movement made in the direction of the promontory is really an upward instead of a downward one, and that relaxation with equal air densities on both of its sides—as did exist in those cases—would not cause it to take that direction.

His description of the state of the membrana tympani of his first case, is strong proof that the concavity was at its minimum, for he states that the "bright spot [is] elongated." Another evidence of the patency of the eustachian tube of this individual, is that the act

of deglutition, performed with the nostrils closed, relieved the disability (4th Prop.), lasting until the same act was performed with the nostrils open, which, with this patient, again gave rise to patency and its consequences.

With his second case, "the bright spot [of the membrane is] much larger than natural," which is strong evidence that its concavity was as nearly flat as the traction of the tensor tympani would allow it to assume. "The rumbling sensation and the deafness are both temporarily relieved by suddenly and forcibly drawing in the breath through the nostrils." (4th, 5th, and 6th Props.) Here the hearing was increased by closing the patent eustachian tube, at the same time abstracting air from the tympanic cavity, and causing the increased concavity of the membrana tympani in a manner exactly similar to some of my cases. He adds, that "The patient has thus acquired the habit [?] of incessantly sniffing the air, which is exceedingly unpleasant to himself and to every one around him."

In the history of his third case he has not been as explicit in his description of what he saw, or the method taken by the patients for relief; but taking into consideration its connection with the other cases, and his using the same expression concerning the method employed for temporary relief, there is evidence enough to consider it to be similar in character. In the latter part of the history of this patient, he states "the hearing remained much better, except during attacks of cold, when the old habit of clearing the ears, by forcing air into them, was had recourse to." It is evident that the habit of "clearing the ears" is similar to those of his other cases, notwithstanding he calls it forcing air into them.

This examination of the history of his cases readily proves that he was mistaken (*a*) in the direction that the membrane took when he instructed them to perform the act of deglutition with their nostrils closed, as this must cause it to rise and approach the promontory, instead of, as he supposed, forcing it outward and away from it; (*b*) consequently, in error as to the cause of the disability in their hearing: and (*c*) in his *theory* that, for normal hearing, the air density in the middle ear must always be equal with the surrounding atmosphere.

Let us compare the facts, as observed in his cases, with his theory :

He says that the eustachian tube must be opened at each act of deglutition for normal hearing.	They find that every time that it is open the hearing is decreased. (1st Prop.)
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He says that the air in the tympanic cavity must "be always of the same density as the outer air."	They are compelled to abstract air (4th Prop.) for the purpose of increasing the concavity of their membranæ tympani (6th Prop.), to increase their hearing, and also for the purpose of <i>closing</i> the eustachian tube.
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Again, while the eustachian tube remained closed (2d Prop.), the increased concavity of the membrana tympani remained stationary (5th Prop.). Now, as this condition of the tube and the membrane is continuous, upon the permanent recovery of the patients, and as there is a process of air exhaustion going on in the middle ear, also continuous, therefore, if the hearing remains uniform, it proves the continous reception of air to the middle ear. (3d Prop.)

While it is evident that the traction of the tensor tympani upon the manubrium accounts in a great measure for the concavity of the membrana tympani, it is seen that the facts observed in those cases prove that it does not maintain its *uniform* concavity, especially that portion of it from which is reflected the "light spot;" and that this condition is maintained by the excess of outside air pressure, as compared with that on its internal surface. When this excess was not present, the membrane assumed as flat a form as its attachments will allow it to take; that is to say, that the unassisted traction of the muscle named maintains it in the same form that a cone, if pressed against it, would do; but the excess of outside air pressure, in addition to this traction, maintains it in a condition that a ball would do if put in the place of the cone; so that a section of the membrane, passing through the *umbo*, would present a curved line, not an angle.

The next case of this class that I will quote, is taken from the "Archives of Ophthalmology and Otology," Vol. II, No. 1, page

107 (1871), reported by Dr. Gustav Brunner, of Zurich, Switzerland.

This case is given in support of the theory, that the closed eustachian tube, assisted by bone conduction—not fluid in the middle ear, as claimed by Gruber—is the cause of the increased resonance or autophony in this patient.

As I wish to employ this illustrative case to prove that it was an opposite condition of this passage, I will be compelled to criticise his conclusions, while accepting the results of his ingenious experiments upon his patient.

His case was a female, "45 years old. Had become deaf after having catarrh the whole winter, but had never before had any trouble with the ear. In April, 1870, sudden pain in right ear, without any distinct history of taking cold." . . . "She now does not complain of any particular pain, but a feeling of stoppage of the right ear; particularly, however, that her own voice resounds very strongly in the right ear in such a manner that speaking is very disagreeable to her; even her own respirations sound so loud and sibilant as to be troublesome. She also hears every motion of the jaws with unusual distinctness." . . . "By auscultation with the otoscope one perceives quite a difference between right and left ear. On the right side the voice of the patient sounds uncommonly loud and hollow, with a tremulous continuation of tone; speech even in common conversation, as though one was speaking in a vaulted chamber or in a long speaking tube, and, on raising the voice, the sound is reduplicated; in quiet breathing, sound through the otoscope remarkably loud and sibilant." . . . "I introduced the catheter on the right side and blew air in by means of the air bag, when I heard a strong roaring or blowing upon auscultation, which made, in spite of its intensity, the impression of a distinct noise arising from the palate, or, at most, from the mouth of the tubes."

"The air douche was without permanent influence upon the phenomena. I now made, in view of Gruber's assertion — although from the result of the examination of the membrana tympani the presence of liquid in the tympanic cavity was not at all probable—a small perforation into the right membrana tympani."

"The autophony was not altered by this proceeding, and no air issued from the opening, in spite of strong and repeated douches of air through the catheter (the tube was, no doubt, still closed). As soon, however, as the air, after repeated efforts, passed through the opening in the membrana tympani with an audible hissing sound, the troublesome resonance, both subjective and objective, disappeared, as if by magic, and did not return when I injected a weak solution of zinc by means of the catheter."

"I remarked particularly that not the slightest secretion made its appearance through the membrana tympani. Now the air passed whizzing through with great ease by the patient's simply blowing the nose, and the improvement continued until next morning. In the evening, however, the patient was no longer able to force any air through the membrana tympani."

"When I saw her two days afterwards the opening was closed; no reaction had followed the paracentesis, but the group of troublesome symptoms were present as strongly as before. State of the membrana tympani same as in the beginning."

" this time the air douche availed nothing. Only after I had blown in some solution of zinc the resonance of the voice suddenly disappeared, and remained absent till the next morning. (To me this observation, which I subsequently repeated, is explained as follows: that after the moistening of the collapsed walls of the tube the stream of air more easily finds admittance.) Two days later the patient presented herself again. The autophony continued with unabated violence. Repetition of the air douche was of no use, and even the injection of fluids at this time proved negative."

If his theory of the cause of the disappearance of the autophony—that is, by opening the tube—is correct, would it not be a more successful method to introduce and retain a catheter in the eustachian passage, as recommended by Dr. Jago, to prove *patency*?* Is it not more reasonable to suppose that the water occupied all of the free space in this small and narrow passage that it would in any opening of the same size and shape, and, while remaining there, would act as an obstruction to the passage of sound in a manner

* Jago on the Eustachian Tube.—British and Foreign Medico-Chirurgical Review, January and April, 1867, page 181.

precisely similar if it had been injected into Dr. B.'s aural auscultating tube while he was examining the ear with it? The following quotations also plainly show that this view is correct, viz.:

"The patient states that the air began to pass into the ears, but was suddenly interrupted. I now pushed a bougie of about 1 mm., in thickness through the catheter. At the middle of the tube it was arrested, and could not be carried any further; but the autophony had now disappeared. If I pulled the bougie back a little the symptoms reappeared, and disappeared again when the bougie was introduced. Thereupon, I took quite a thin bougie, $\frac{3}{4}$ mm., which was also arrested at the spot mentioned, and found great resistance, but at last entered the cavitas tympani; whereupon, the autophony ceased, even with the otoscope."

"I usually injected a solution of zinci sulphas (grs. iij, 3j), and I remarked particularly that the injected liquid never produced autophony; on the contrary, it disappeared, as I observed above, sometimes not from the effect of the air douche, *but by blowing in a few drops of liquid.*"

"Violent sneezing would sometimes bring on autophony, as also merely stooping, *whilst continued gargling often caused it to disappear.* When the autophony is absent the patient feels much more comfortable, and says she hears better, although with the watch no marked difference can be noticed."

Such an array of symptoms, all pointing plainly one way, namely, that she heard the sound of her voice through an unusual avenue to her ear, is not to be excelled, even in the history of Dr. Jago's case, related of himself. Yet he repeats, on page 117, "It appears to me most natural at present to seek the cause of its frequent alternations in a stoppage of the tubes."

"That such really existed is shown by the result of the auscultation, and by the fact that the solution of zinc injected through the catheter never or seldom occasioned any burning in the ear."

I think that it is not necessary to spend much time in criticising his conclusion, that the auscultation demonstrated stoppage of the tube, for the quotations already given state, as plainly as can be, that he heard with the aural auscultating tube introduced into her ear. "On the right side the voice of the patient sounds uncom-

monly loud and hollow," "in quiet breathing sounds remarkable loud and sibilant;" and the sound from the catheter gave "the impression of a distant noise arising from the palate, or at most from the mouth of the tube." Even if he had desired to describe the symptoms of patency, as proved by this phenomenon, observed during this experiment, he could not have used more expressive or descriptive language.

The history of this case will suggest, upon reflection, that the reason that the injection of the zinc solution did not reach the cavity of the tympanum, might not have been on account of closing of the eustachian tube, but, on the contrary, *because of its being too open*. I consider that the fact of his inability to successfully inject the solution into the tympanic cavity of this patient, is another evidence of the correctness of my opinion—that is, that this case had an abnormally open eustachian tube, so that "air could either enter or recede from the tympanum."

Evidently, if the tube had been long closed, there must have been rarefaction of the air in the tympanum by absorption; therefore, just as soon as equalization of the air density transpired upon the opening of the tube by the injection, the liquid must of necessity have been forced into the cavity by atmospheric pressure at the same moment, or before the air entered it.

I am free to affirm, that it is almost impossible to force a liquid into a long, narrow tube, similar to the one under consideration, with one of its extremities closed, because of the condensation of the air in the further extremity of the tube, by this procedure; and that the only method by which a fluid can be made to enter such a passage with facility, is, as is found in long-closed eustachian tubes, by a rarefied condition of the air in the tympanum, occasioned by absorption. I mean by this, that it is not probable that a fluid can be injected into a tympanic cavity having a patent eustachian tube, and an imperforate membrana tympani, because the air already in the tympanum and the tube—which cannot be condensed—has no avenue for escape, the tube being too small in caliber to allow the liquid to enter and the air to come out at the same time; but if there had been a perforation of the membrana tympani, then there would have been no difficulty in injecting the solution into the tym-

panum, for the air in the cavity could and would escape through this opening in the membrane.

He gives other reasons in the support of his theory, that the abnormally closed tube always accompanied this autophony, but the only one I will mention is found on page 118. Its ingenuity and seeming correctness call for attention. He says: "It might seem strange that tympanophony did not appear during the introduction of the bougie, but we shall cease to wonder at this when we consider that the tube is not a round, but a fissure-shaped canal; the bougie cannot, therefore, fill up the whole cavity, but will act as a wedge, holding the walls asunder."

Keeping in mind the comparative dimensions of this "collapsed-tube" shaped passage and the bougies, I think that it is a little doubtful that even the larger one would act as a wedge, holding the walls above it or below it sufficiently apart for the sound of her voice to enter, without taking into consideration that at the same time there was a constriction—*which must have been membranous and nearly circular*—so great that it could not be made to pass, and the one of $\frac{3}{4}$ mm. required pressure to overcome "great resistance." How could the sound pass through that part of the tube occupied by this membranous and circular constriction, while the larger bougie filled it to its utmost capacity? But we are told that the phenomenon disappeared while the bougie was pressing upon this constriction, only occupying the anterior half of the tube, leaving all posterior to this unopened. There are no facts related here that say the sound from the larynx entered the middle ear by this passage under these circumstances.

On page 115 he gives what must be considered as positive evidence that there had been no *closure* of the eustachian tube, but the *opposite* condition, viz.: As the hearing increased "from 0 to 16 centimetres," he says, "The injection of the membrana tympani has disappeared, and it shows instead a grayish cloudiness, *and some increase of concavity*—nothing particular." (4th, 5th, and 6th Props.). What could increase the curvature of this membrane? Facts and recognized authority answer, air absorption within the middle ear, causing rarefaction. As this air abstraction could not thus effect it with an open eustachian tube, it proves a closed one. That this is the normal condition of the tympanic air density, is proved by the

fact, that increased hearing was concomitant with the increased concavity of the membrane and closure of the tube.

On page 124 he gives his theory of the cause of these phenomena :

“To return to the history of our patient, the reason why only her own voice and breathing, but not the sounds produced outside and in the air, showed a strikingly louder and changed tone can only be that, in the first instance, the source of sound lies in our own body, and that besides, the conduction through the outer air, the conduction through the solid parts exert an influence.

“From this circumstance we must explain the augmented resonance of the voice. Taking it for granted that complete closure of the tubes is favorable to resonance in the drum, it will appear nevertheless strange that resonance appears only in the sound of our own voice, and not likewise in that of others, and we are obliged to seek the conditions for this resonance in the conduction of the bones.”

The effort in these two sentences is to prove that the autophony is propagated to the ear by the conductive property of the bones, assisted by complete closure of the tube. Indeed, he must consider this bone conduction as the greater cause, for he has admitted that we have too large a class of cases of obstructed tubes without autophony to place much stress upon this condition of the passage as occasioning these phenomena.

The property of conduction in any substance is not changeable suddenly, but in this case we are forced to say that it was arrested in increasing the resonance of the voice, by the air douche, by a few drops of fluid injected into the eustachian tube, by gargling, by the large bougie that could not, according to his opinion, open the whole length of the tube, and by the smaller one that did, after considerable force, penetrate to the cavity, for all of them did cut off the increased resonance of her voice. But did they at the same time change the conductive power of the bones? Was not this property in them just the same after the resonance had disappeared as before? He says: “By auscultation with the otoscope one perceives quite a difference between the right and left ear.” No one can doubt but that the bone conduction must have been equal on both sides of the head.

On page 110 he relates two experiments, viz.: "All these phenomena, subjective and objective, completely disappeared when the right ear was filled with water; the patient's own voice then sounded as usual. This was also the case upon stopping the auditory canal by strongly compressing the tragus, but upon opening the auditory canal all the symptoms reappeared immediately."

I have made the same experiment—only once—on one of my patients, who had an imperforate membrana tympani (Case IV, Rev. Dr. C.), with the same result. My explanation at the time, and the facts seemed to bear me out, was that the column of water interfered with the vibrations of the membrane, and that this interference also occurred from the closure of the auditory canal by the condensed air pressing upon the imperforate membrane. It will be remembered that pressure, without the means of condensing the air, did not thus effect the resonance. It will also be remembered that this patient observed that when only a few drops of water were on the membrana tympani it had but little effect, but when filled the autophony was gone. That the glycerine in the auditory canal of Miss K. (Case V) should have the effect of stopping the increased resonance is not to be wondered at, because it passed directly through the perforated membrana tympani into the eustachian tube, closing the avenue for the sound to reach the ear, requiring only two or three drops to do this. Strong pressure on her tragus had no influence whatever in diminishing the autophony; but with the Rev. Dr. C. it had a modifying effect, but only when the canal completely closed at the same time.*

I will now make some quotations from an article written by Dr. Jogo, of England. He has contributed two papers upon the subject of Patency of the Eustachian tube in the British and Foreign Medico-Chirurgical Review, one in the January and the other in the April numbers, 1867.

I desire to use these quotations merely for the purpose of showing that I am not mistaken with respect to the character of the cases just given; that they are, as asserted, those of abnormally open eustachian tubes.

He was afflicted with this very annoying disease, and devoted

*See foot note, page 13.

quite an amount of time to various experiments upon his ear, and carefully noted the symptoms accompanying the disease and these experiments. There is not any probability of his being mistaken when he says that "It is now full fourteen years since I have understood the phenomena which an open eustachian tube entails."

I will make the quotations from pages 181, 182 and 183:

"But I am confident that any one who may provide himself with a tube open at both ends, just the size to pass through a nostril into the throat, and having projecting from it another near one of its ends suitable for being passed into the eustachian tube may, by thus introducing this into one of his tubes *so that the air may pass freely from it into the drums*, verify all my main experiments."

"In proof of this explanation I may adduce that, whenever I have been teased by the patency of the tube, I have always been able to *close it for some instants by an inspiratory movement, with nose and mouth stopped.*" (4th, 5th and 6th Props.)

"I will subjoin, that in explosive expirations, or in speaking, coughing, hawking, sneezing, the pressure upon membrana tympani is painful, and in the more violent, particularly involuntary kinds, threatened its integrity." "Every word spoken whilst the tube is open strikes the membrana tympani through it, and is thus heard many times louder upon this ear than upon the other. The eustachian tube is minute as compared with the external auditory canal, and can only admit a fraction of the volume of air that the latter holds. And, therefore, I do not mean to affirm that my experience of speaking into my own eustachian tube is so stunning as what happens when another person speaks into the external one with his lips applied to the auricle. Yet, the illustration is so correct that, with a due allowance for the difference pointed out, it will convey a fair idea of the nature of the shock."

"Inspiratory sounds are also heard through the tube, but then only in a very faint manner."

On page 185 he relates a case similar to his own. "About a dozen years ago a young woman, a member of a church choir, with only a very slight appearance of faucial relaxation, and a slight elongated uvula, with no other sign of ill health than a slight anæmic look, narrated symptoms essentially like those before us."

"She had herself discovered and practiced the mode of *reducing her bulging outward membrana tympani by trying to breathe with shut nose and mouth.*" (4th, 5th and 6th Props.)

Were it not for the rare description of this disease of the eustachian tube, either in our Books or Journals, a less amount of space and a less number of cases would have sufficed to prove all that was undertaken, namely, that the mere opening of the eustachian tube into the tympanum is a cause of too great a disability to the organ of hearing to suppose that the renewal of air to this cavity is accomplished by the "deglutition method," and that, while this passage was open, the membrana tympani was in a relaxed or less concave condition than it was when either temporary or permanent recovery had taken place.

The result of experiments contradicts the supposition that the pathological condition of this passage, aside from the patency—which affects the hearing only from a physical cause—had much influence in producing these phenomena. That mere patency did have this effect has been frequently and clearly demonstrated; and that this effect of the opening of the tube is not due to its pathological condition is just as clearly proven by the fact that the instant this passage was closed by the abstraction of air from the cavity before the inflammation of the mucous membrane that caused it had subsided, the whole train of symptoms at once disappeared, remaining away while the tube was closed. When the patients were successful in this abstraction of air and closure of the tube, they were also successful in banishing the entire phenomena of patency and most of the disability of their hearing. Their inability to keep this passage permanently closed was the only reason that compelled them to seek the assistance of the Aurist, otherwise they would not have complained of their hearing.

It will be remembered that I stated that Mr. Toynbee was mistaken about the condition of that portion of the eustachian tube, just beyond the attachment of the tensor palati, during the act of deglutition; consequently in error in his deductions arrived at in his first experiment.

It is generally considered that the act of deglutition, in immediately removing the prominent symptoms, and the main disability to

the hearing, occasioned by the inflation of the middle ear, by the Valsalvian method, is proof of the complete opening of the eustachian tube into the cavity, and the complete restoration of the usual degree of acuteness of hearing. This has been received by the Medical Profession, and passed by them, as far as known to me, unquestioned, or rather, untested by any special or exact measurement during the experiment.

It will be found, upon close observation, that the hearing is not as perfect for a short time, immediately after the prominent symptoms, occasioned by the inflation of the cavity, have been made to disappear by the act of deglutition, as it was previous to the inflation. The following method of making this experiment, with a normal ear, will prove the correctness of this assertion, viz. :

First Experiment.—First, attach one end of a long thread to a watch, retaining the other extremity in the hand, then find the utmost hearing distance from the watch (in the usual method of testing the hearing), placing the taut thread up to the nose; the length of this thread, from the nose to the watch, being the normal hearing distance from the watch. Second, now inflate the tympanic cavity by the Valsalvian method, then immediately perform the act of deglutition, and instantly note the hearing distance from the watch on the thread. *This will be found to be a little less than it was before the inflation*, only returning again to the usual hearing distance after a short period of time.*

*The following are the reports of a few of my friends, who tried this experiment at my request :

"Feb. 9, 1868.—I heard the watch nearly twelve feet. I then blew my breath in my ears, producing a great fulness. After I swallowed some saliva this left me entirely; but I had to step half a step nearer the watch to hear it, and in a few minutes, not more than two or three, I heard it again better than before.

"JAMES E."

"July 29, 1872.—After repeated efforts, I overcame the desire to swallow a second time, and found that the usual hearing returned in from three to five minutes after the first act of swallowing. If I swallowed two times, it returned sooner; even if I swallowed as often as I desired, I was still compelled to wait certainly over half a minute for the usual hearing to return.

"J. C. W., Lebanon, Ill."

"Aug. 6, 1872.—(Watch covered.) Inflated my ears, and immediately swallowed twice, and heard at second knot ($14\frac{3}{4}$ inches) natural, in 26 seconds [23 inches].

E. A. H., Collinsville, Ill."

This shortening of the hearing distance demonstrates that the air did not all escape from the cavity during the act of deglutition. (1st and 2d Props.) If the eustachian tube was opened all the way into the middle ear, the air within and without the tympanum would have been instantly equalized, allowing the membrana tympani as instantly to resume its normal position for as perfect hearing as there was before the inflation. Evidently there was a small portion of the eustachian tube that was not opened by the action of the tensor and levator palati muscles, and that the part or portion of the tube that was not opened offered so little resistance to the passage of the superabundant air contained in the cavity that the tensor-tympani muscle, assisted by the natural resilience of the membrana tympani, was able to force out a sufficient quantity of this air to relieve the ear of the prominent symptoms occasioned by its presence; still leaving too much in there for the usual hearing to return, compelling the experimenter to wait a short time for the mucous membrane of the cavity to absorb the remaining portion of the superabundant air (that the act of deglutition could not give opportunity to escape), which allowed the membrana tympani to become more flat than normal. After waiting for the consummation of this rarefying process the usual degree of hearing returned.

I will now make a few quotations from recognized authorities, with the view of bringing prominently before the mind, that it is a requisite of normal hearing that there should be a uniformity of air density in the tympanic cavity; and by the same authorities, and experiments, and cited cases, I will show that there is a continual absorption (or, at least, a disappearance) of air within the cavity, and, consequently, a corresponding supply. (3d Prop.)

The arguments based on these quotations—the result of these experiments, and the detailed statements of the cases cited, will show that there is a greater uniformity of air supply, according to the views here presented, than can be done by the “Toynbee method;” that is to say, that the means of furnishing air to the cavity must operate as continuously as the absorption, and that this “deglutition method” is not, and of necessity, in the nature of the case, can not, be as uniform in replenishing air to the cavity as its abstraction by absorption from the cavity.

In the quotations, I wish the following points to be kept prominently in view : first, the assumed necessity of uniformity of air density in the cavity for normal hearing ; second, the necessity for a method of supply to maintain this uniformity ; therefore, the problem presented by them for solution is this: how can these two imperative necessities be maintained at the same time ? They affirming that this is done by the action of certain muscles, opening the eustachian tube all of the way into the cavity during the act of deglutition.

Toynbee, on page 192, explaining his method of maintaining a uniform air density in the tympanum, says: "During the few moments that the faucial muscles are brought into play in the process of deglutition, air can either enter or recede from the tympanic cavity, and thus be always of the same density as the outer air." On page 193 he gives his reasons why a constant supply of air is necessary, saying: "Although from the preceding remarks there can remain little doubt that the faucial orifice of the eustachian tube is ordinarily closed, except during the act of deglutition, it is requisite to perfect hearing that the tube should be pervious, and that there should be a constant interchange of air in the cavity of the tympanum. If the eustachian tube becomes impervious, the air that was in the tympanum at the time of the closure gradually disappears. It is not easy to decide whether it is absorbed, or whether by a kind of exosmose it passes through the membrana tympani; but whatever the cause, in a space of time varying in different cases from a few hours to a day or two, there is no doubt the air in the tympanic cavity becomes partially exhausted. The effect is to produce an increased concavity in the external surface of the membrana tympani; a forcing inward of the chain of ossicles; pressure on the contents of the labyrinth; and a very serious diminution of the hearing power."

In the last edition of "Troltsch on the Ear," page 180, the author says, speaking of the eustachian tube, "It serves an outlet for the secretion of the latter (the cavity), but especially as a passage for the renewal of the air in the middle ear. It is, therefore, a ventilation tube, by means of which the meeting of strata of air of equal density before and behind the drum is made possible, and the air in the

tympanum maintained of the same degree of tension as that of the external atmosphere."

Again, on page 187: "But if the tube is at the same time to be a ventilation tube, by means of which a regular exchange of air between the pharynx and the cavity of the tympanum is brought about, it is necessary that its regular and frequent gaping or opening should take place only in this wise, that the strata of air before and behind the membrana tympani be kept of the same tension and density that is requisite for a normal vibratory capacity for the drum. Experience has shown that such an opening of the tube takes place with every act of deglutition."

It will be seen that the chief purpose of the authors is to rationally account for the fact of a uniformity of air density in the tympanic cavity, and they aim to prove that this is accomplished during the act of deglutition.

My effort will be to demonstrate that this mode of replenishing air to the tympanum is not so "frequent" as to admit of its being as "regular" as the abstraction of air from the cavity—that is to say, that the mucous membrane, in exhausting the air in the closed tympanic cavity, is more uniform in its action than the act of deglutition, irregularly performed, can be in its supply to this cavity.

It seems to me that it is superfluous to say, that there is no possibility of this cavity being *uniformly* supplied with air by an *irregular* act; yet, according to the quotations, the tympanum must await upon such an act. Keeping in mind the constancy and rapidity* of air absorption within the cavity, the longer the interval of time between those acts that supply this air the greater must be the variation between the internal and external air densities; therefore, good hearing must of necessity be of an intermittent character, synchronous with the act of deglutition. The following experiment will help to test whether this is the case or not.

Second Experiment.—Let the experimenter place a watch (with a thread attached to it and employed for the same purpose as mentioned in the First Experiment) as far from his ear as he can hear it, marking this place on the thread by a knot; remain in this position without performing the act of deglutition for a number of hours. It

* See 4th Experiment, and Cases VI and VII.

will be found that his hearing the tick of the watch at the end of two hours will be just as acute as at the beginning of the trial, and that he could hear the sound at any time he turned his attention to it during this experiment.*

It is certain that in this condition of the eustachian tube there could not have been as uniform a supply of air to the tympanum as there must have been uniform absorption of air within the cavity, and yet the hearing is just as acute after this long non-performance of the only act that Toynbee, Troltsch and others allow for the renewal of air to the cavity, as before the experiment, when he swallowed as often as he desired.

The result of this experiment seems to prove one of two facts—viz.: (a) That either there was no rarefaction of air within the tympanum by absorption, (b) or that the supply of air to the cavity must have permeated the eustachian tube as continuously as it was requisite to maintain the normal tympanic air density. (3d Prop.).

Every case of that numerous class known as “Obstructed Eustachian Tubes,” on account of chronic inflammation of the mucous membrane lining them, will bear the same evidence as this experiment and the first one—viz.: that at the act of deglutition this pas-

* The following are the reports of a few of my friends who attempted this experiment, viz.:

“March 10th, 1868.—I commenced to listen to the tick of father’s watch at 3 o’clock, but was compelled to swallow before the first three minutes passed, then I did not swallow for nearly twelve minutes, then I swallowed in five minutes, the next time I did not swallow for nearly one hour, but my throat [by this time] was very dry. I heard the watch one time as well as the other. JENNIE E. D.”

“March 10th, 1872.—Commenced to listen to the watch (covered) at 2 o’clock P. M., and swallowed only when I was compelled to, at 2.03, 2.06, 2.26, 3.03, 3.16, 4.08, 4.25½, 4.44, and 5.37. I heard the watch equally well all the time, but my throat was a little sore when I got done. BELLA R.”

“March 21st, 1872.—I made the same experiment, and swallowed at 1, 1.08, 1.46, 2.20, 4.13, 5.12, 6.27. Distance just 6 feet. I heard the watch this time also as well at one time as another. BELLA R.”

“April 8th, 1872.—Commenced to listen at 9 A. M., and did not swallow, because my throat was very sore [occasioned by tonsilitis], until 11.30 A. M., and then only because I forgot. Commenced again at 1.30 P. M., and did not swallow for just three hours. My hearing was not very good when I started, but was equally good at any time I listened to the tick of the watch. H. LEE J.”

sage is not opened into the tympanum, yet the amount of their hearing proves that the air slowly and continuously permeates through the abnormally closed tubes into the middle ear, although not sufficiently rapid for good hearing. That there is air permeation in this condition of the tube in all such cases of this class is evident, because of the degree of hearing being much greater, and the concavity of the membrana tympani much less, than in cases having acute tubal catarrh, where little or no air can enter, because of excess of secretion. If the air does not enter the cavity at all, then the deafness would be as great as in any case of complete closure of the tube, and the concavity of the membrana tympani would also be as great, for the length of time giving opportunity for air absorption is certainly long enough to accomplish this. It is also just as evident that the air does not enter the tympanic cavity during deglutition, for if this act opened the tube, what would hinder the hearing from being instantly increased, as it is by the inflation of the cavity by the Politzer air douche? That the hearing is increased by this inflation, I take it, is strong evidence that the eustachian tube was not opened into the cavity at the act of deglutition. It may be claimed that the action of the tensor and levator palati muscles in those cases do at least give some opportunity for air to enter the cavity, but not sufficient on account of the thickening of the mucous membrane of the tube. Then relief for all such cases is constantly at hand; is it not evident that the prescription to perform frequent acts of deglutition would be the remedy, thus allowing more air to enter the cavity; making the Politzer air douche needless; and that the continued exercise of this faculty would increase the hearing, until the one-sided pressure on the membrana tympani was neutralized, and its normal position attained?

The following experiment will not only corroborate the views here expressed concerning air permeation through the normally closed eustachian tube, but will show more demonstratively than any experiment yet given that air can enter the tympanum without the aid of the act of deglutition, even more rapidly than is required; showing that there is no necessity for any action of the tensor and levator palati muscles to open this passage to the middle ear for the normal renewal of air to this cavity.

Third Experiment.—First find the utmost distance from the watch with the aid of the thread, as before stated; note this. Second, close the nostrils with the thumb and forefinger, and perform the act of deglutition several times, thus abstracting the air from the middle ear, so as to decrease the hearing as much as possible; immediately after this again find the hearing distance from the watch, and note this on the thread; continue every five minutes to make these observations of the hearing distance for a period of half an hour, all this time refraining from performing the act of deglutition. It will be found that the hearing distance from the watch will continuously increase, although there has been no act to open the eustachian tube to assist in replenishing the cavity with air.*

Evidently the cause of this increase of hearing distance from the watch, under these circumstances, is due to the tympanum being again replenished with air, so as to allow the membrana tympani to return to its normal position. But from what direction did this air come?—by what avenue? I take it that this is as conclusive evidence as could be required to prove air permeation through the normally closed eustachian tube into the cavity.

Although the celerity of the air exhaustion within the cavity is not in dispute, it is nevertheless evident that great importance must be attached to the rapidity of this disappearance, when the question

* "COLLINSVILLE, ILL., April 24th, 1872.—Found the normal hearing [watch covered] at length of this (shorter) string [48"] at 9 A. M.; swallowed with nose closed and heard at first loop [38½"] at 9.04 at original distance. Swallow and heard at same. [Repeated several times.] E. A. H."

"ST. LOUIS, April 24th, 1872.—First found distance [64¾"] that I heard the watch, then I cut the cord, closed my nose and swallowed

At 12.45 P. M., and heard at 1st knot [48¼"].

At 12.50 " " " 2d " [60⅝"].

At 12.52 " " " full length [64¾"].

Second trial.—At 8.35 P. M., heard at 1st knot [49⅜"].

At 8.40 " " 2d " [54¾"].

At 8.45 " " 3d " [61¼"].

At 8.50 " " 4th " [62⅞"].

At 8.55 " " 5th " [67"].

At 8.57 " same as at the start [69⅞"].

AMELIA F.

(Teacher in one of the Public Schools.)

of air supply to the tympanum is under consideration, as slow abstraction only requires slow renewal, but rapid abstraction an equally rapid supply. For the purpose of placing this important function of the mucous membrane prominently before the mind, so that due importance may be attributed to the method of supplying the depletion thus continually going on, the following experiment is given, viz.:

Fourth Experiment.—First find the utmost hearing distance from the watch, aided by the thread in measuring as before mentioned; note this. Second, inflate the middle ear by the Valsalvian method, thus forcing, by superabundant air, the membrana tympani away from its normal position, dragging with it the ossicula auditus; immediately after this inflation again note on the thread the hearing distance. Continue making these observations every five minutes for half an hour, refraining from performing the act of deglutition during the experiment. With those experimenters whose eustachian tubes are normal, this inflation will decrease the hearing; and with those having an inflamed mucous membrane of this organ, lessening the opportunity for air to enter the middle ear, it will increase the hearing; and with those whose tubes allow an excess of air—bordering on patency—it will decrease the hearing; but with either party it will be found that the usual amount of hearing will soon return. As this usual hearing could not return until the membrana tympani and ossicula auditus also returned to their usual position, it is, therefore, conclusive evidence that the superabundant air was abstracted by some means, and as the act of deglutition was not performed, it must have been rapidly taken away by the action of the mucous membrane of the cavity.

From the result of this experiment it is evident that air abstraction from the tympanum is not a very slow process.

We have other means of measuring the rapidity of the air absorption in this cavity. For this purpose I will relate, as briefly as is consistent with the importance of this subject, the observations made on the following cases of closed eustachian tubes by acute tubal catarrh, viz.:

CASE VI.—Master Freddie H., aged about nine years. Examined first on July 25th, 1866. Has suffered for about three weeks

from a very severe cold in the head; his throat was also much affected; tonsils enlarged; breathed entirely through the mouth. Supposed cause, prolonged bathing. Hears the watch in both ears only on slight pressure; has considerable pain in the ears, and under them toward the throat. The membrana tympani of both ears were very concave.

Attempted to inflate the tympanic cavities by the Politzer air douche, but failed; also failed on the 26th, but on the 28th was successful in opening the left tube, increasing the hearing in this ear to 12" (normal hearing distance of the watch about 120").

Aug. 3d.—Hearing to-day same as before treatment; was again unsuccessful in inflating either cavity.

Aug. 4th.—His mother accompanied him to-day, stating that his improved hearing of last Saturday did not last until he got home. Was again unsuccessful in inflating the tympanic cavities.

Aug. 6th.—To-day opened both tubes by the air douche. The hearing was not examined before the treatment, but this inflation increased this in the right ear to 13", in left to 15".

Aug. 7th.—Watch heard with both ears only when nearly in contact. One successful air douche increased the hearing in right to 9", left to 11". Three other douches to 14" on right side, and 17½" on left.

Aug. 9th.—Hearing in right 2½", in left 4". After inflation of middle ears by seven air douches his hearing was increased to 18" in right, and 22" in left. This was about 10.30 A. M. He did not leave the office until 12 M., when, on examination, his hearing with right ear was 7", left 10". Here was a loss in one and a half hours on the right side of 11", on the left 12". Three more douches increased the hearing to 21½" and 27", respectively.

Aug. 10th.—To-day there was a loss in two hours of 13" in right, and 18" in left.

Aug. 11th.—Loss to day in one and a half hours 7" in right, and 13½" in left.

About the same amount of loss of hearing followed the next four treatments; this was also noticed by the father of the patient. The observation of this decrease of the hearing so soon after the treatment was first made by the mother of the patient (who was a teacher

in one of our public schools); and it was her remarks about it, that were the cause of its being noted by me.

CASE VII.—The next case in which I took notice of the amount of hearing lost after treatment, was my niece, Miss Lizzie I. R., aged ten years. Her tonsils were very much enlarged. Hearing watch with right ear contact, left 1". The first inflation caused a very loud crack in her ears, frightening her very much. After this air douche she heard the watch with the right ear 18", left 32". I tried for about half of an hour to persuade her to allow me to make another application of the douche, but in vain. Her hearing at this time was reduced 11½" on right side, and 19" on left, a loss during this half hour of 6½" in right, and 13" in left. Four days afterward—March 9th, 1867—her hearing on right side was contact, left 1½"; after one air douche, right ear 17", left 35"; after another, right 22", left 46"; then was compelled, on account of the very great dread of the effect or noise that the inflation caused, to desist until 2 P. M., when her father came to my assistance. After she had been away nearly four hours, her hearing had decreased to 12" on right side, and 27" on left, a loss in this time of 10" on right, and 19" on left.

The history of quite a number of similar cases could be added, demonstrating the rapidity of the absorption or disappearance of air within the cavity of the tympanum.*

If the "deglutition method" of renewing air to the tympanum is correct, the experimenter that refrained from performing the act of deglutition for two hours, must have been as deaf as either of those cases having tubal catarrh, two hours after their treatment, for neither, according to the Toynbee theory, had any means or opportunity of supplying air to the middle ear, in the place of that abstracted by the mucous membrane of the cavity, and this should have caused an equal loss of equilibrium in the tympanic air density in both individuals, consequently an equal loss of hearing; but the results prove that those having normal eustachian tubes did not suffer in this respect, by reason of this long so-called closure (3d Prop.); whereas, those cases having abnormally closed eustachian tubes, did

* I have observed the hearing decreased by this means at the rate of from 13" in two hours to 16" in five minutes.

seriously suffer loss of their hearing, even after a much shorter period of closure.

The Fourth Experiment, and the facts observed of the VI and VII Cases, abundantly prove that even if the act that is claimed to open the eustachian tube was performed every minute during life, it would not be sufficiently "frequent" to maintain the requisite uniformity of air density in the cavity to admit of perfectly uniform hearing. A continuous air absorption necessitates a continuous renewal. Either you must stop the continuous abstraction, or you must allow the continuous supply. The alternative is physically unavoidable.

Again, I deem it self-evident that a uniform tympanic air density implies that there *must* be a uniform condition of the eustachian tube; therefore, this passage must be uniformly open, or uniformly closed. It is impossible that it can be closed a large majority of the time, and open at accidental intervals, and there exist at the same time a uniform air density in the tympanic cavity while air absorption is continuous. Now, if the walls of the eustachian tube are constantly in contact, or only in contact during the interval between the acts of deglutition, in what condition will the air that remains in the cavity be in respect to its density, as compared with that on the outside? Most certainly it will soon be in a rarefied condition (4th Prop.), unless it can as freely and continually enter the cavity as if it had a patent tube to admit it. Even if the "deglutition method" of tympanic ventilation is correct, much the greater period of time, this air in the cavity must be in a rarefied condition, as the absorption is rapid enough to produce this effect upon it, and the act of deglutition is not "frequent" enough in its supply to prevent it. From this it appears as though there would be a necessity for a patency of the eustachian tube,—that is, if the normal air density in the middle ear must—as asserted by Toynbee, Troltsch, and others—be maintained equal to that of the surrounding atmosphere; but instead of this, there is, in my opinion, a physical necessity for a rarefied condition of the air density in the middle ear, even if the eustachian tube was only closed for a short period of time, to allow the oscillations of the membrana tympani to move with greater freedom and sweep, and prevent undue condensation of air in the tym-

panum from the vibrations of the membrane occasioned by the waves of sound.

RESUME.

The First Proposition—"That during the act of deglutition the eustachian tube is not an open passage into the tympanum"—has been sustained by the fact that the increased concavity of the membranæ tympani of those patients that recover from the disability of their hearing occasioned by the patency of their eustachian tubes, as compared with its curvature before their recovery. We have seen that after their hearing has been permanently increased the act of deglutition does not cause their membranæ tympani to become less concave as it did before their recovery. Now, as we know that they increased the concavity of their membrane by abstracting air from the middle ear, and as the closure of the tube was necessary to maintain this concavity, it is evident that if the act of deglutition opened the tube, this maintained curvature would be instantly released, allowing the membrane to become less concave, consequently give rise to the well-marked phenomena of patency, as it did in Mr Toynbee's first case, and my second.*

The First Experiment (also Mr. Toynbee's first, page 190,) demonstrate that the eustachian tube is not completely opened during the act of deglutition, but only so much of it as to make it possible for the natural resiliency of the membrana tympani, assisted by the traction of the tensor tympani, to force out sufficient of the superabundant air that occasioned the prominent symptoms that follow filling the middle by the Valsalvian method, still leaving too much air in the cavity for the usual hearing to return, as proved by exact measurement, aided by a thread, compelling the experimenter to wait a short time for the mucous membrane of the tympanum to exhaust the remaining excess of air—that did not have opportunity to escape during the act of deglutition—that permitted the membrane to assume a less concave condition than normal. After the consummation of this rarefying process the usual degree of hearing returned.

Every case, whose hearing is limited on account of chronic inflammation of the mucous membrane of the eustachian tube, will bear the same evidence. If the act of deglutition opened their eustachian tubes, why does it not increase their hearing as instantly as does the Politzer air douche? That they require this inflation to increase their hearing, is the strongest proof that air did not enter the tympanic cavity during the action of the tensor and levator palati muscles. It cannot be admitted that the action of these muscles allow *any* air to enter the middle ear; if this was the case, then frequent acts of deglutition would make the air douche needless, and that the continued exercise of this faculty would increase the hearing, until the one-sided pressure on the membrana tympani was neutralized,

* See pages 10 and 19.

and its normal position attained. Nor would it be correct to assert that their middle ears did not receive any air, as this would cause them to be as deaf as cases afflicted with acute tubal catarrh.

The Second Proposition—"That the walls of the eustachian tube are constantly in slight contact"—is substantiated by the uniform constancy of the concavity of the membranæ tympani of those cases of patency of the eustachian tube after their recovery. It is evident that the increased concavity of their membranæ tympani was concomitant with their increased hearing, and that the increased curvature was caused solely by air abstraction, and this rarefaction could not in this way affect the membrane with an open tube. The continuance of the increased concavity proves a constantly closed eustachian passage.

The failure of the return of the usual degree of acuteness of hearing, after the act of deglutition relieved the symptoms occasioned by inflation of the middle ear, as shown by First Experiment, also proves that the entire length of the eustachian tube was not opened by the action of the tensor and levator palati muscles.

The Third Proposition—"That the air continuously permeates the eustachian tube into the tympanum, thus maintaining the normal air density"—is proved by the continuance of uniform hearing in every normal ear. It is well known that there is absorption of air in the tympanum which must be removed; therefore, if this supply is uniformly added, the concavity of the membrana tympani is also necessarily uniform; but, if infrequent and irregular, the shock of its entrance would suddenly affect the membrana tympani, consequently the hearing. Therefore, this mode of renewing air to the middle ear would give rise to an irregular hearing, which is not in accordance with our observations.

That the air does permeate the eustachian tube, is shown by the Second Experiment—that of refraining from performing the act of deglutition for two hours without affecting the acuteness of hearing in the least degree. Whence did this experimenter receive a uniform supply of air to maintain this uniform hearing? If we will compare this result with the facts observed in VI and VII Cases, that had abnormally closed eustachian tubes, because of acute tubal catarrh, whose loss of hearing one and a half hours after inflation of middle ears were 12" and 13" respectively, we will find in the contrast another evidence of the truth of this Proposition. It is apparent that the eustachian tubes of the experimenter—in the Second Experiment—and those of the patients just mentioned, were what is usually understood as closed, consequently they were equally circumstanced as to their opportunity for renewing the air in their middle ears; but the results prove that the experimenter, having normal tubes, did not have his hearing affected in the least by this long so-called closure, but those having abnormally closed tubes were seriously affected in their hearing after a shorter lapse of time.

That the air can permeate the eustachian tube even faster than is

necessary for the normal ventilation of the tympanum, is proved by the Third Experiment—namely, that of abstracting air from the middle ear by performing the act of deglutition while the nostrils are closed, then refraining from swallowing during the experiment, thus decreasing the hearing. It will be found that the hearing will return to its usual degree of acuteness in a few moments. There can be no doubt but that the cause of this increase of hearing, under these circumstances, is due to the tympanic cavity being again replenished with the normal amount of air, even more rapidly than is requisite for the normal supply to this cavity.

The Fourth Proposition—"That the air in the normal tympanic cavity is not of equal density with that on the outside, the air in the tympanum being rarefied"—is proved by the observation that there is increased concavity of the membranæ tympani of those cases of patency of the eustachian passage that improve in their hearing. We have seen that this increase of curvature did not take place when the air densities on both sides of the membrane were equal, and that the act that the patients performed for the relief of their disability of hearing abstracted air from the cavity, causing the membrane to recede inward, thereby increasing their hearing. The co-existence of these facts affirm that the air in the normal middle ear is in a rarefied condition.

The Fifth Proposition—"That one of the functions of the eustachian tube is the maintenance of this normal air density"—is sustained by the evidence of the necessity of an increased concavity of the membranæ tympani, in cases suffering from abnormally open eustachian tubes, for increased hearing. It is evident that the rarefaction of air in the middle ear that sustains this concavity, must be maintained by a graduated and uniform entrance of the supply into the tympanum.

The Sixth Proposition—"That the rarefied condition of the air in the tympanum is the cause of the uniform concavity of the membranæ tympani, especially that portion from which the 'light spot' is reflected"—is substantiated by the observation made by the methods that patients afflicted with abnormally open eustachian tubes take to reduce their flat membranæ tympani to a more concave condition—*i. e.*, making an inspiratory effort, or performing the act of deglutition with their nostrils closed. There are no facts showing that the combined action of the circular and radiating muscular fibres in this organ maintain its normal concavity. We have seen that patients who have abnormally flat membranæ tympani improve their hearing by a voluntary act (rarefying the air in the middle ear) that cannot restore any muscular inability that might be said to affect it. It has frequently been observed by Aurists that a cicatricial portion of a membranæ tympani is always concave. It is certain that this formation has no circular or radiating muscular fibres; its uniform concavity cannot be said to be maintained by such means.

